The Method in general

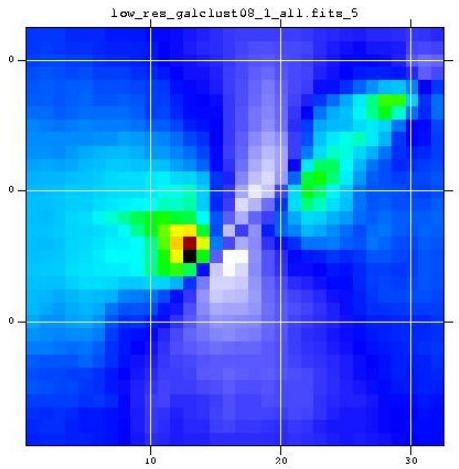
- Non-parametric GalaxyCluster Reconstruction using weak and strong lensing constraints.
- Least χ^2-Reconstruction with respect to lensing potential ψ
- $$\chi^2 = \chi^2_w + \chi^2_s$$
- Combination of both lensing effects to use all avaiable knowledge and to reduce individual weaknesses of both effects

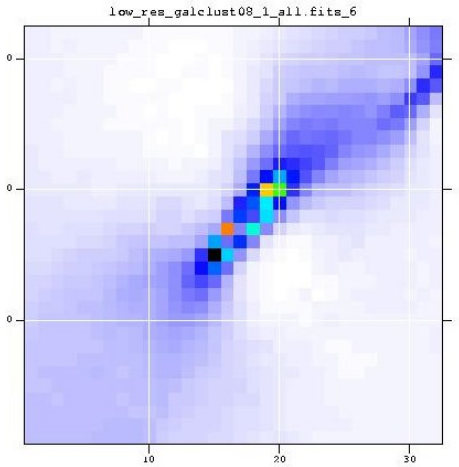
Weak Lensing

- Weak lensing is based on the relatively small distortion of background galaxies
- To get a solid signal one has to average over a number of galxies per pixel, this limits the resolution of weak lensing
- $\chi^2_w = \sum_{i=1}^{N} \frac{|\epsilon_i(\psi) - \hat{\epsilon}_i(\psi)|^2}{\sigma^2_{iw}}$
- For the expectation value of ellipticities you get:

$$\hat{\epsilon} = \begin{cases} \frac{\gamma}{1-\kappa} & \text{for } |1-\kappa|^2 + |\gamma|^2 > 0 \\ \frac{1-\kappa}{\gamma^*} & \text{else} \end{cases}$$

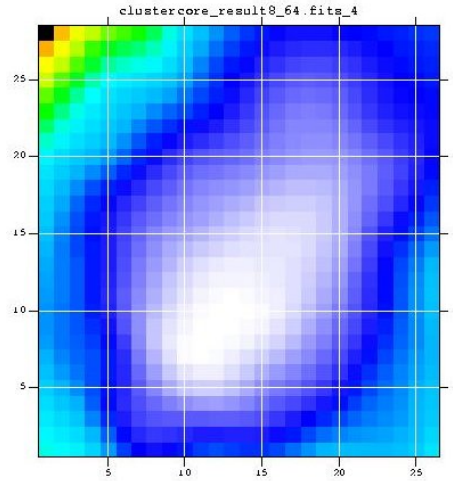
- σ is given by error in ellipticity measurement and intrinsic source ellipticity

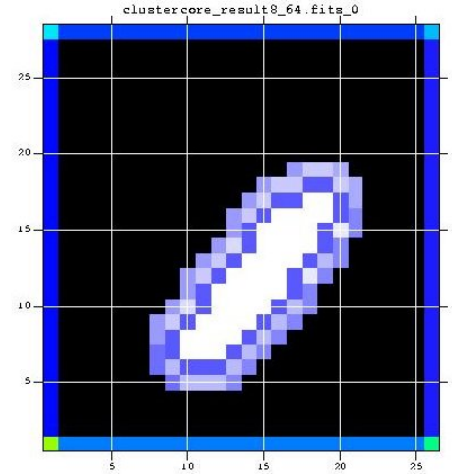




Strong Lensing

- Strong lensing reconstruction is based on critical curve constraints
- On the critical curve the Jacobian should vanish
- $\chi_s^2 = \sum_{i=1}^{N^*} \frac{(det\mathcal{A}(\psi))_i^2}{\sigma_{is}^2} = \sum_{i=1}^{N^*} \frac{[(1-\kappa(\psi))^2 - |\gamma(\psi)|^2]^2}{\sigma_{is}^2}$
- σ describes your uncertainty on critical curve position
- critical curve position can be obtained by observed arc positions
- To follow critical curve grid resolution can be refined and focused on cluster core





Implementation

- Numercial solution of the χ^2-minimisation with respect to ψ
- Based on grid methods using finite differences and linearisation of differential equations
- Weak-lensing input can be a ellipticty-catalogue with field information
- Strong-lensing input can be a map of the estimated critical curve on approriate resolution and in right coordinates
- For both, constraints erros have to be given

Code-Facts

- Implemented in C++ ($\backsim$ 10000 lines)
- External libraries:
  GSL: Vector., Matrix-handling, linear systems
  NR: Interpolation methods
- Almost no "by-hand" adjustment necessary
- Runtime: 3-5 hrs depending on weak lensing resolution
- Could be parallized
- Memory: $<$ 50 MB

Results: Simulated Cluster

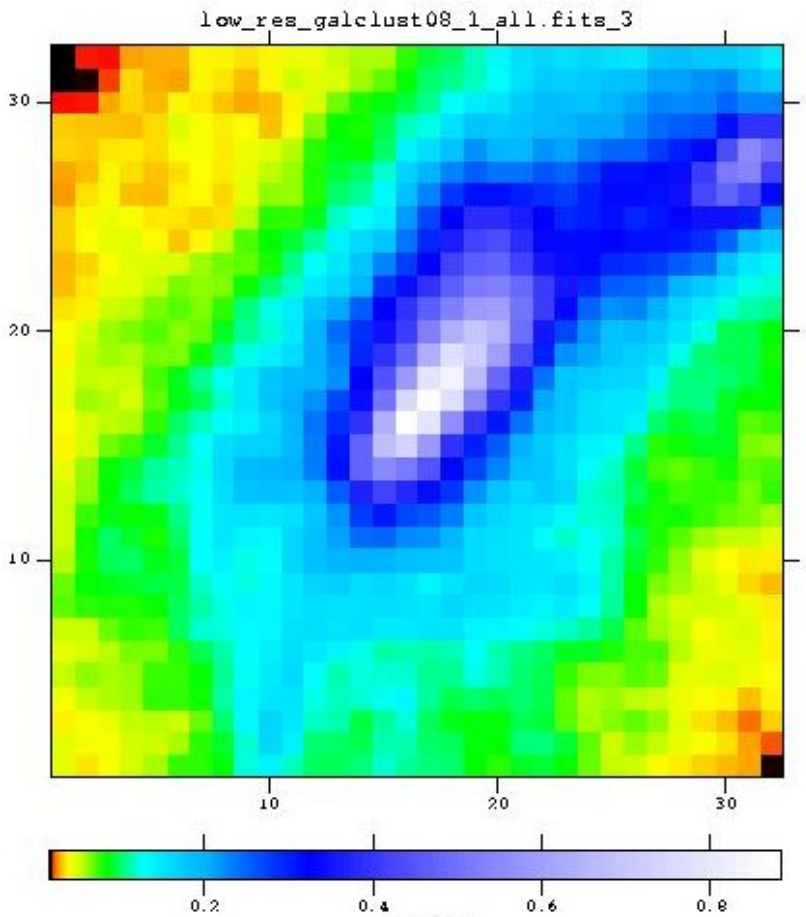


Figure: Original Cluster

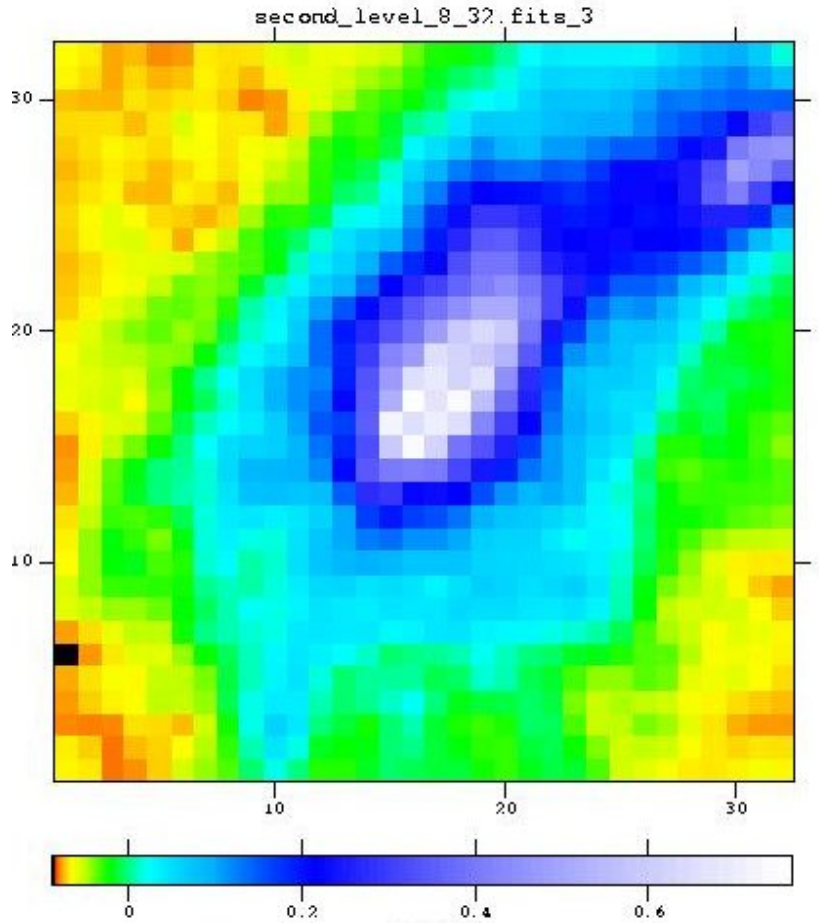


Figure: pure weak lensing reconstruction

Results: Simulated Cluster

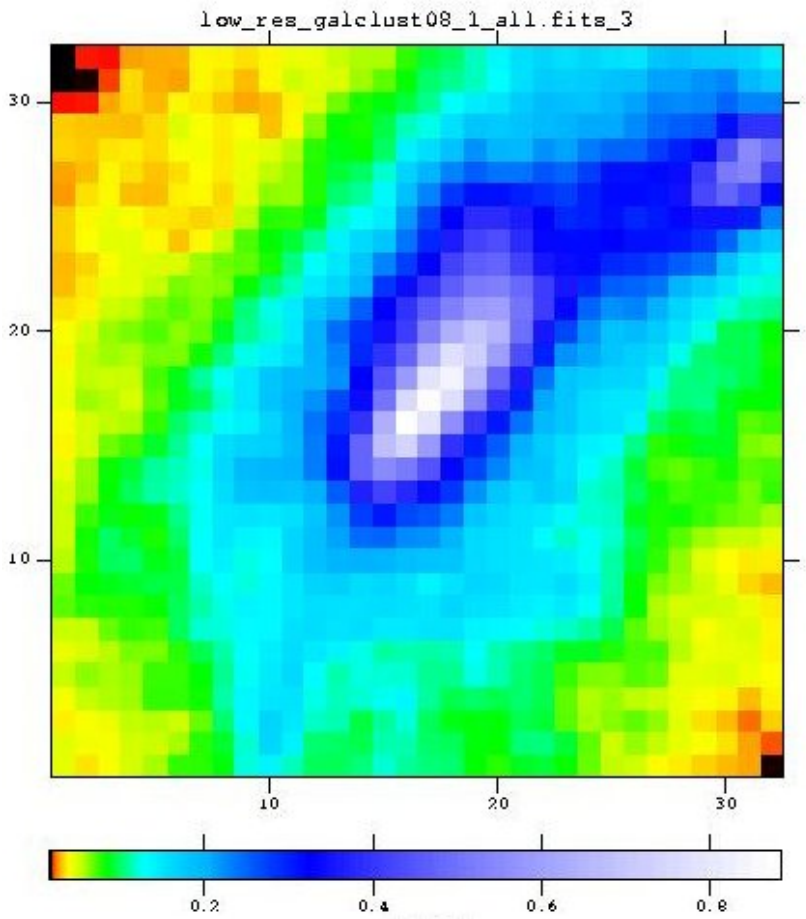


Figure: Original Cluster

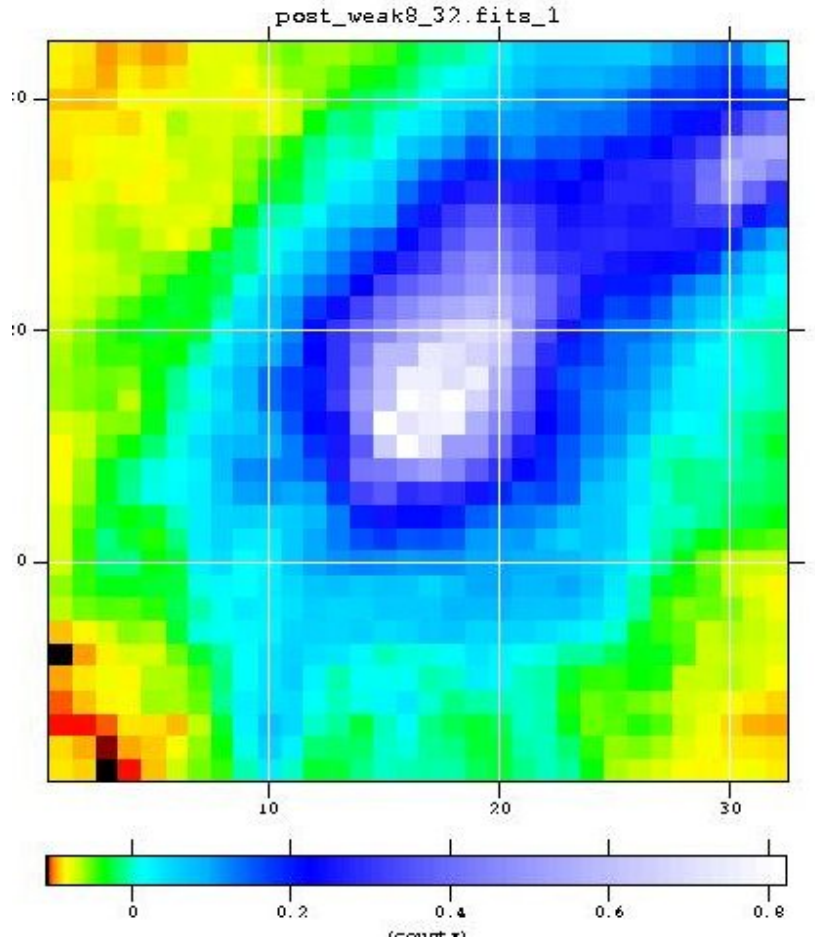


Figure: combined weak and strong lensing reconstruction

Results: Simulated Cluster

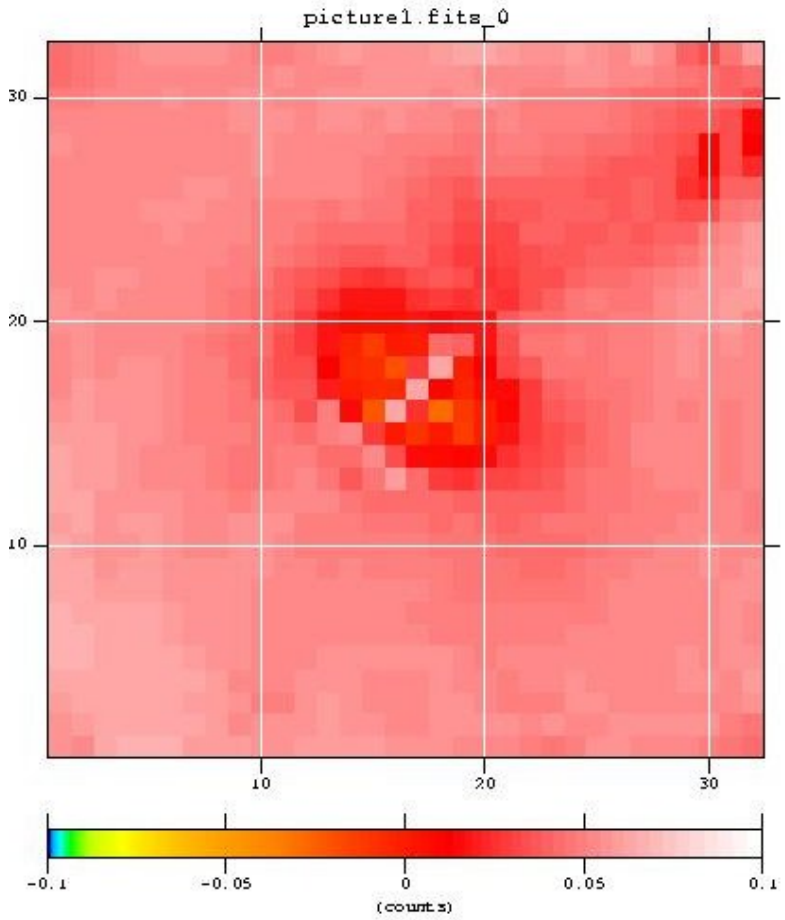


Figure: Residuals pure weak lensing

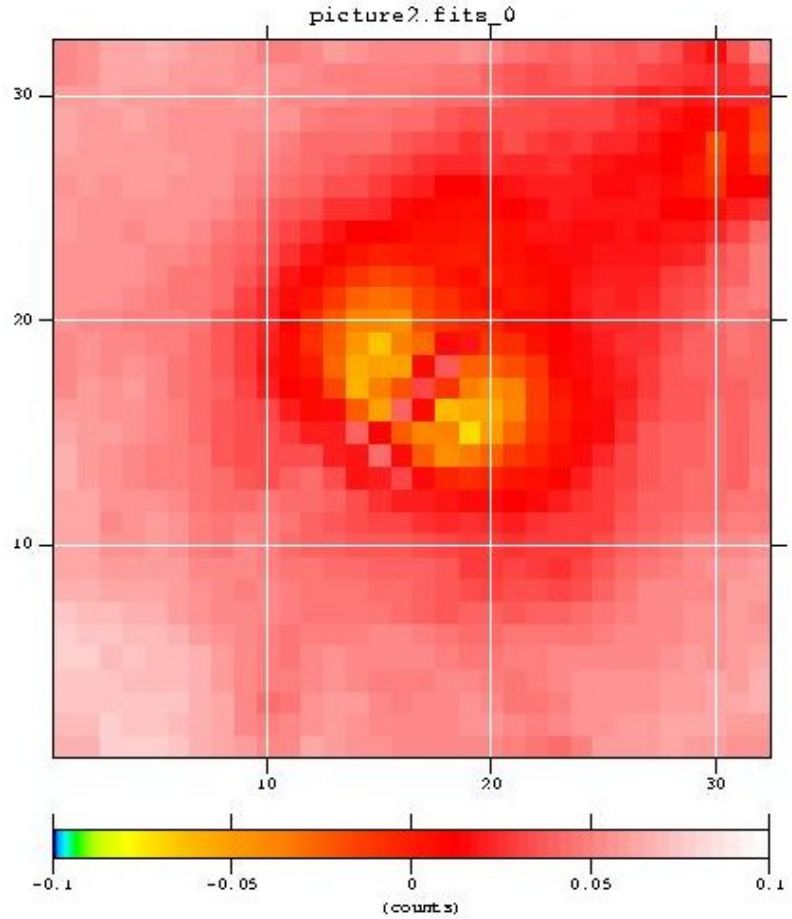


Figure: Residuals combined weak and strong lensing reconstruction

Results: Simulated Cluster

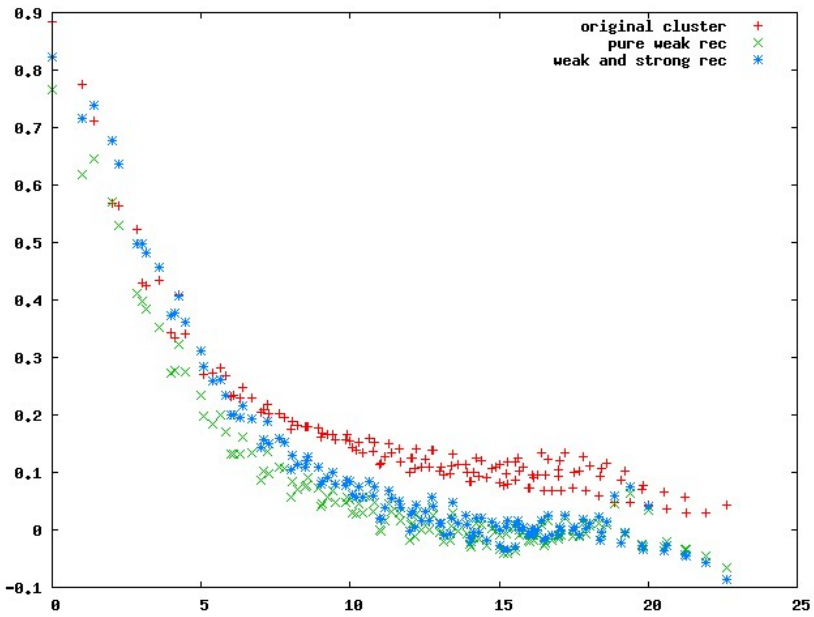


Figure: Radial density profile

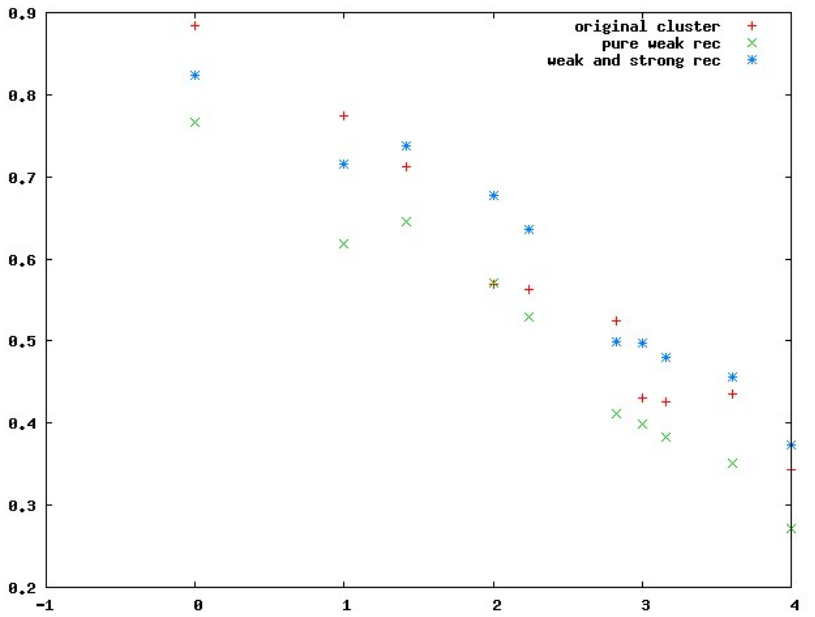


Figure: Zoom at the profile

Results: Simulated Cluster

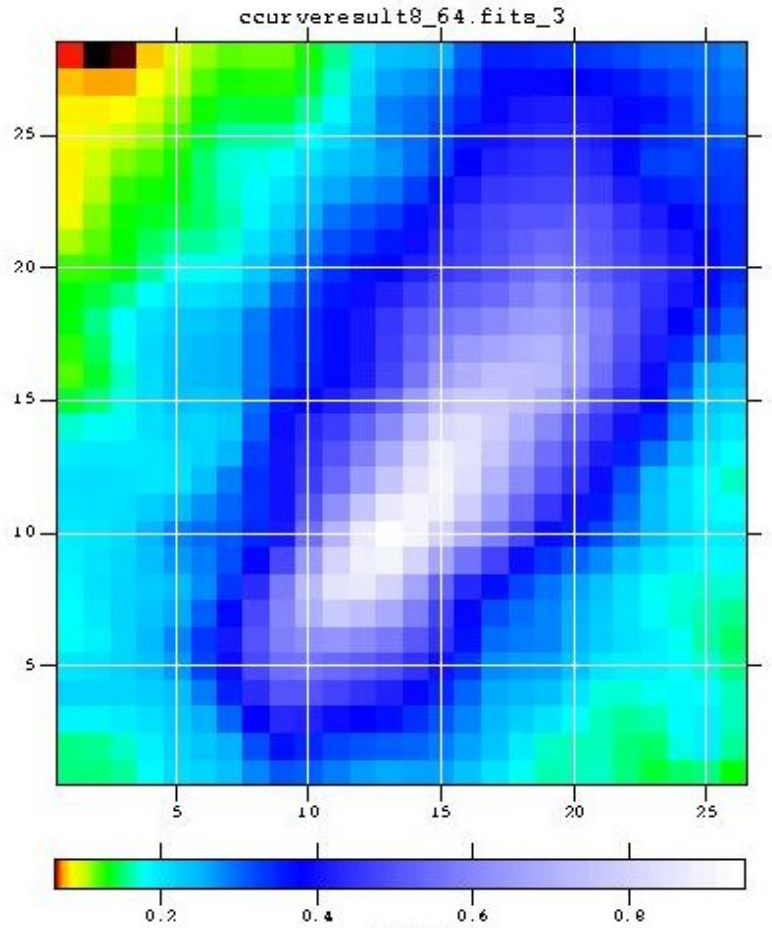


Figure: Zoom on original cluster core

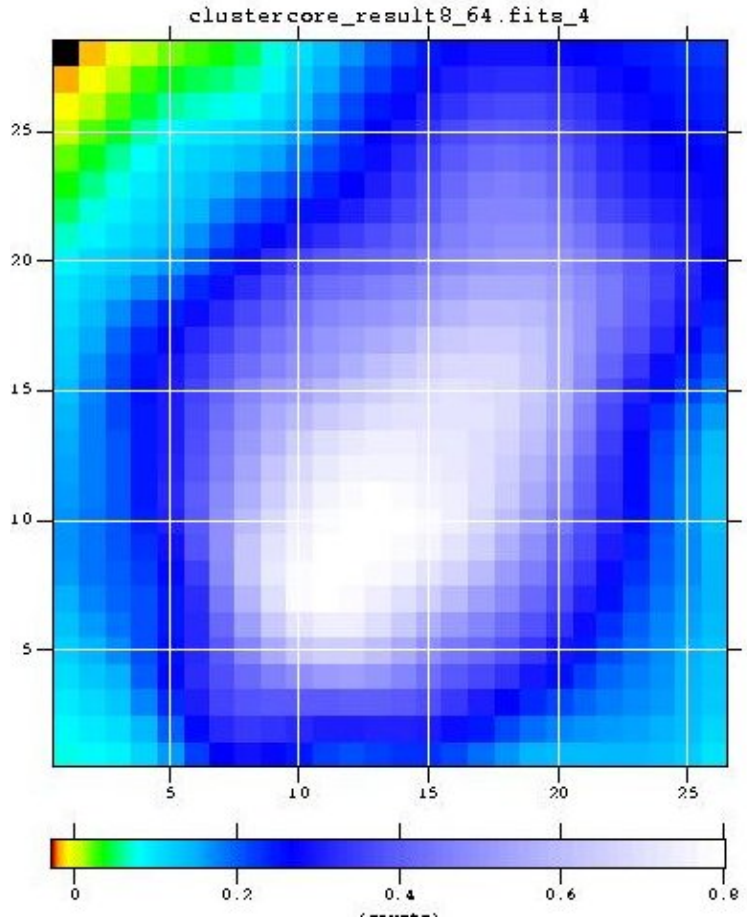


Figure: Interpolated Reconstruction

Results: Simulated Cluster

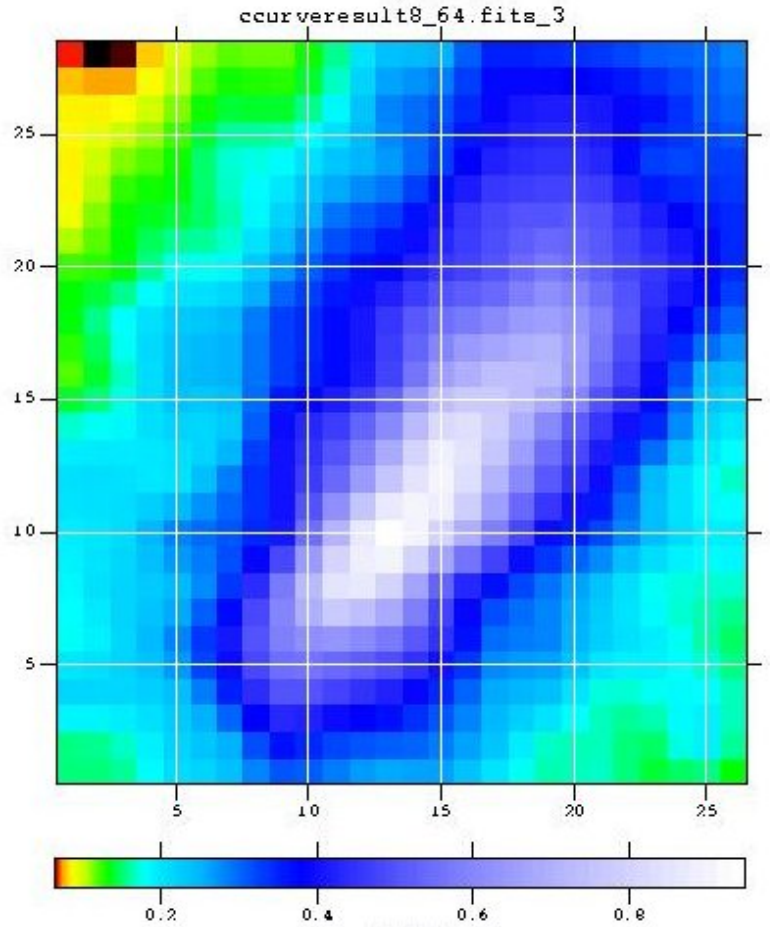


Figure: Zoom on original cluster core

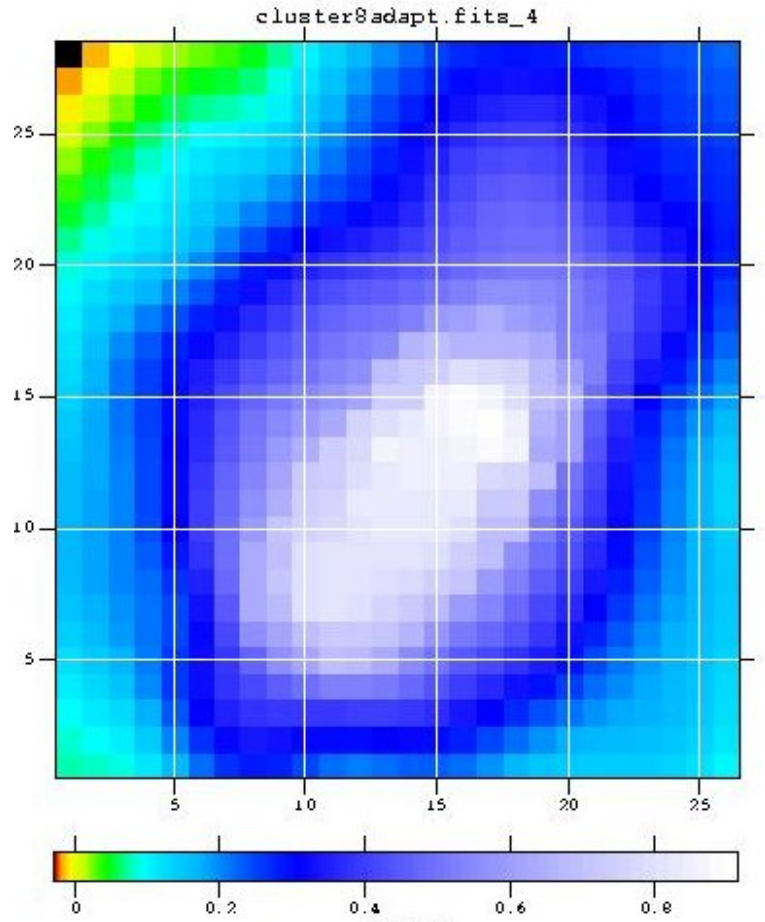


Figure: Reconstruction on higher resolution

Results: Simulated Cluster

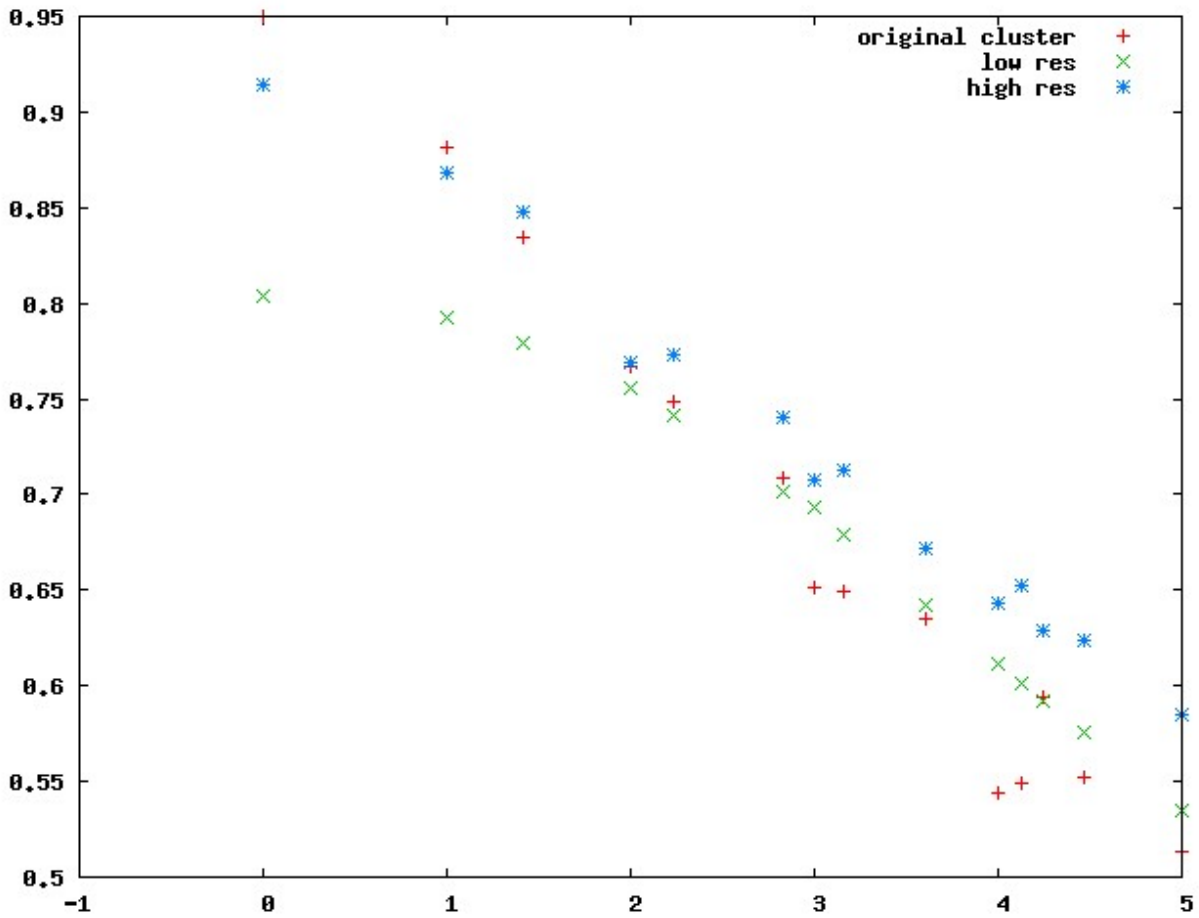


Figure: Radial density profile on high resolution